A Future Perspective for Digitalization of Egyptian Ports (Opportunities and Challenges) Case Study: Alexandria Port Authority

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المستخلص

برز اعتماد التقنيات الرقمية في الموانئ كتوجه رئيسي في الصناعة البحرية، حيث تسعى الدول إلى تحقيق الرخاء الاقتصادي من خلال عملية التحول الرقمي. ويتسق هذا الاتجاه مع التحرك العالمي نحو الرقمنة في مختلف المجالات. تعد الرقمنة عنصرًا أساسيًا في عملية تحويل البيئة المحيطة إلى بيئة ذكية. تتيح الإجراءات الآلية في عمليات الموانئ والتجارة ميكنة عمليات الموانئ واللوجستيات، بالإضافة إلى عمليات مراقبة الموانئ المستقلة، النقل ،الاستلام ونقل البضائع ذاتية القيادة، وخدمات التحميل والتفريغ الآلية للسفن. بالإضافة إلى ذلك، فإن اعتماد السفن المستقلة وغيرها من التقنيات المتطورة من شأنه أن يحسن فعالية الموانئ، مما يؤدي إلى تقليل الاعتماد على القوى العاملة البشرية.

علاوة على ذلك، فإن استخدام تقنيات الاستشعار والتقنيات اللاسلكية سيكون واسع النطاق في إدارة الموارد والموانئ. مثل الطائرات بدون طيار، سلاسل الامداد، مصادر الطاقة البديلة، والشبكات الذكية. الهدف من هذه الدراسة هو تحويل ميناء الإسكندرية إلى ميناء ذكي واتخاذ الإجراءات اللازمة لتحسين وتطوير كفاءة وأداء الميناء في كافة الأوجه.

بدأت الرسالة بتصنيف الثورة الرقمية إلى ثلاث عصور منفصلة، تغطي الفترة من ١٩٨٠ إلى ٢٠٢٢وسرد مختصر للأحداث الحاسمة في كل جيل وأهميتها و التحديات التي واجهتها، والتقدم العلمي المحرز وتقنيات معالجة البيانات المستخدمة في كل عصرمع توضيح الغرض من تكنولوجيا المعلومات. ومن أجل تحسين عمليات الموانئ وزيادة الكفاءة إلى أقصى حد. تم عرض التحليل في تأثير ونطاق كل جيل، بالإضافة إلى إجراء فحص شامل لمفهوم الموانئ الذكية.

تناقش هذه الرسالة تحول الموانئ البحرية منذ ما قبل الستينيات وحتى العام الحالي. كما تستكشف المعايير المختلفة للموانئ الذكية وأهميتها في تحسين الفعالية ومدى فعالية وسرعة الأنشطة في الميناء وجودة التكنولوجيا المستخدمة مع تطبيق الأنظمة المعاصرة والمتطورة في إطار التحول الرقمي، مما أدى في النهاية إلى اكتساب الخبرة من ميناء سنغافورة الذي يعتبر ميناء مثالي في صناعة النقل البحري، علاوة على ذلك تم عمل فحص شامل لمحطات الميناء الرئيسية والمشاريع القادمة للميناء ، بما في ذلك مشروع TUAS الواسع

النطاق. الميناء مخصص لتعزيز الابتكار والإبداع البحري. تستكشف الرسالة تأثير أجهزة الاستشعار الذكية على قدرات التتبع لدى سلطات الموانئ ومشغلي المحطات وهم مسؤولون عن تشغيل وصيانة الهياكل والمرافق المينائية والتي لها أهمية تاريخية.

استخدمت الدراسة منهجية بوكس جينكينز ٢٠٢١، من خلال المركز الإحصائي لميناء الإسكندرية، وتطبيق خطواتها على السلسلة الزمنية للفترة من ٢٠١٤ حتي ٢٠٢٣. تم تحليل بيانات عينة الدراسة في المراحل التالية: مرحلة التعرف، مرحلة تقدير النموذج، ومرحلة التنبؤ، لتوقع مستويات الأداء خلال الفترة من ٢٠٢٤ إلى ٢٠٢٨. كما تم إجراء مقارنة بين ما تم تطبيقه في ميناء جبل علي وسنغافورة وروتردام، والوضع الحالي لتطبيق الموانئ الذكية في ميناء الإسكندرية، بهدف تقديم توصيات لتحديد متطلبات تحول ميناء الإسكندرية إلى ميناء ذكي.

Abstract

The adoption of digital technologies at ports has emerged as a key trend in maritime industry, as nations endeavor to achieve economic prosperity through the process of digital transformation. This trend is consistent with worldwide movement towards digitization in various domains. Digitization is an essential element in process of converting surroundings into an intelligent environment. Automated procedures in port operations and trading enables development of advanced and automated terminals, as well as independent port control operations.

The aim of paper is to present a proposal to transform port of Alexandria into a smart port and execute necessary measures. The analysis began by classifying Digital revolution into three separate epochs, covering period from 1980 to 2022. An abridged chronicle of crucial occurrences in every generation and their importance. The challenges faced, scientific progress made, and data processing techniques employed in each era. A clarification of the purpose of information technology. In order to improve port operations and maximize efficiency, the analysis also considered the impact and scope of each generation, as well as conducting a comprehensive examination of the concept of smart ports.

The BOX-JENKINS methodology, ARIMA models and EVIEW software were used to analyze the time series for the years 2012–2021 through the statistical center of Alexandria Port Authority. The steps of this package were then applied to the study's sample data in the following stages: Identification Phase Model Estimation Phase Forecasting Phase and Prediction of Performance Levels from 2022–2026. In order to establish the requirements for Alexandria Port's transformation into a smart port, a comparison was done between the smart port application already in place at Damietta Port and what was implemented at Singapore, Tangier Med Port and Rotterdam.

Keywords: Digital Twin. Port Efficiency. The Internet of Things. Artificial Intelligence. Port performance. Smart Ports. Digital Transformation.

1- Introduction

Egypt possesses an extensive array of maritime ports, encompassing prominent commercial ports situated on both the Red Sea and the Mediterranean Sea, as well as smaller ports and several specialized ports as in Figure (1) dedicated to mining, tourism, and fishing. Egypt's extensive coastlines on the Mediterranean Sea, Red Sea, and River Nile, spanning a total of 2,900 kilometers, have a significant impact on the country's social and economic welfare due to the influence of marine activities (Saleh et al., 2006).

Figure (1): Commercial Ports in Egypt
Source: Maritime Transport Sector (MTS), (2023)

Ports and harbors are widely recognized as crucial drivers of national and regional development, serving as vital lifelines. They are purposefully designed as strategic instruments for regional development, meticulously constructed and managed in accordance with this objective. Consequently, the ports in Egypt serve not only as conventional maritime transportation hubs, but also encompass a diverse range of additional roles, encompassing aspects such as industry, distribution, logistics, and Sustainable Development actions. There has been a significant increase in the utilization and advancement of Electronic Data Interchange (EDI) in recent years. In general, a considerable number of platforms are subjected to processing within control rooms. The primary objective of these control rooms is to centralize extensive amounts of data from various departments engaged in all port operations. Consequently, the port's operational efficiency and competitiveness will be improved and can be measured.

Figure (2): Egypt's Strategy for Digitalization
Source: Ministry of Communication, (2023)

The objective of the Egyptian Maritime Transport Sector, as well as the objective of the Egyptian Political Leadership, was focused on the development of ports, digital transformation, and digitization across various domains, particularly within the Maritime Transport sector. This strategic approach aims to position Egypt as a leading player on the global stage and leverage its inherent capabilities and strategic geographical location.

2- Research methodology

The methodology of this thesis is a mixture of descriptive and comparative analytical approaches, including suitability and testing of various components of proposed platform. The study also critically assesses various performance and efficiency of global ports. It has been reached through the following tasks:

The thesis described level of efficiency and regression that happens to Alexandria Port due to lack of experience in coping with technological development. Also, describing criteria and standardization that global ports perform and evaluate its results and gathering data using primary and secondary data.

3- Generation of ports

The development of seaports, especially those that handle containerized cargo, results in the establishment of an increasingly intricate web of relationships between the supply and demand sides of the port services industry. The significance of seaports could be stated by grouping them

according to a specific port generation. Ports of the first, second, third, and fourth generations can be identified in line with the UNCTAD model. The local community and port users (customers) were proposed as two stakeholder groups to be included in the fifth-generation port in 2011.

In 1990, the United Nations Conference on Trade and Development (UNTACD) put forward a conceptual framework for categorizing seaports. This framework considers factors such as the port's development strategy, the variety of services it offers, and the extent to which information technology is integrated into the entities operating within the port services market. This text aims to summarize the evolution of seaports before the 1960s, followed by the widespread implementation of containerization in the 1970s.

Subsequently, seaports experienced further growth in the 1980s due to the adoption of advanced technology, efficient machinery, computer systems, and intermodal operations. As per the UNTACD classification, only the biggest seaports in the world, situated at the intersection of major shipping routes, have the capability to operate as integral components of highly advanced global logistic platforms. These platforms handle a significant portion of the total cargo flow.

Table (1) displays the ports generations model proposed by UNCTAD.

Port characteristics	1st generation	2nd generation	3rd generation
Development period	prior to 1960	1960-1980	after 1980
Main cargo	Semi-bulk cargo	Dry semi-bulk cargo and liquid bulk cargo	Bulk, general, and containerized cargo
Attitude and strategy of port development	Conservative, means of transport change point	Expansive, transport, industrial, and commercial centre	Commercial, logistic-distribution centre for international trade
Scope of operations	[1] Loading, unloading, storage, navigation services	1 + [2] Cargo processing, industrial and commercial services - territorial expansion	1 + 2 + [3] Cargo and information distribution, logistic operations

Organisational features	Independent operations within the port, informal connections between the port and its users	Closer ties between the port and its users. No connections between different types of operations within the port, provisional ties between the port and the city	Unified port community. Port integration with the transport-commercial chain. Close connections between the port and the city. Extensive port organisation.
Specific production features	Cargo flow, simple, single services. No/low added value	Cargo flow, cargo processing. Various services, higher added value	Cargo and information flow. Cargo and information distribution. Wide package of various services. High added value
Deciding factors	Work/capital	Capital	Technology, know-how

Figure (3): Port marketing and the challenge of the third-generation port
Source: UNCTAD, (1995)

3-1 First generation of seaports

According to UNTCTAD, the primary characteristic of the first-generation seaport is the straight forward process of moving cargo between land and sea-based transportation methods, known as stevedoring. The seaport functions independently from transportation and commercial activities.

By leveraging its dominant position in the local market and frequently enjoying a monopoly, it is not obligated to make efforts to fulfil the users' needs. The first-generation port's information, document, and statistical system operates independently from the port users. The relationship between the harbour and the port city is sufficiently flexible that there is no requirement for both entities to coordinate their plans for spatial development.

3-2 Second generation of seaports

According to UNCTAD, the second-generation ports are connected to their surroundings through their transportation, industrial, and commercial functions. Industrial parks are established within port regions to handle imported raw commodities transported by sea, including iron ore, steel, crude oil, aluminium, paper pulp, artificial fertilizers, sugar, flour, and other agricultural goods.

3-3 Third generation of seaports

The development of third generation seaports occurred in the 1980s during a period of rapid growth in containerized cargo volumes, the establishment of intermodal links, and the growing

demands brought about by the expansion of international transportation. These generations exhibit greater activity levels compared to previous ones, as they actively seek for cargoes by pursuing a development plan that promotes the establishment of integrated logistics centers and logistics platforms that facilitate international trade.

Third generation ports in the operational region are distinguished by their extensive range of services, encompassing four distinct sectors of commercial activities. The first category includes the provision of stevedoring, storage, and navigation services, utilizing advanced technologies, efficient organization and effective management.

3-4 Evolution of fourth generation of port

In 1999, UNCTAD introduced the concept of a fourth-generation port. The evaluation has taken into account the following factors: the standard of port services, the use of information technology, the advancement of the port community, the existence of a port cluster and logistics center, the quality of linkages with the inland areas and the coastal areas.

Unlike the third-generation ports, the fourth-generation ports have a significant function as a hub, serving as the primary regional port from which cargo is delivered by sea to smaller outlying ports. Port authorities can be linked together through a shared administration, as seen in the example of ports in Copenhagen and Malmo, or by a shared operator for the container terminal. UNCTAD highlights those investments in port-hubs are typically carried out by the private sector, particularly by robust international firms that specialize in managing port terminals, primarily those dedicated to container operations.

4- Milestones of Digital Transformation in ports

The exchange of information is as important to freight movement as the movement of the cargo itself or the equipment that is moving it. In freight transportation, if information does not move, cargo does not move. The more seamless the information flow is, the quicker cargo can get from its origin to its destination.

Electronic Data Interchange (EDI) communications facilitate the smooth handling of cargo from mode to mode, as well as automating billing, data entry, tracking functions, and other information exchanges such as cargo manifests, vessel arrival times, inbound movements, and status notifications.

Within context EDI can reduce cycle times, forward documents, improve inventory management, plan schedules, and make purchases, in an electronic and automatic way as in Figure (4).

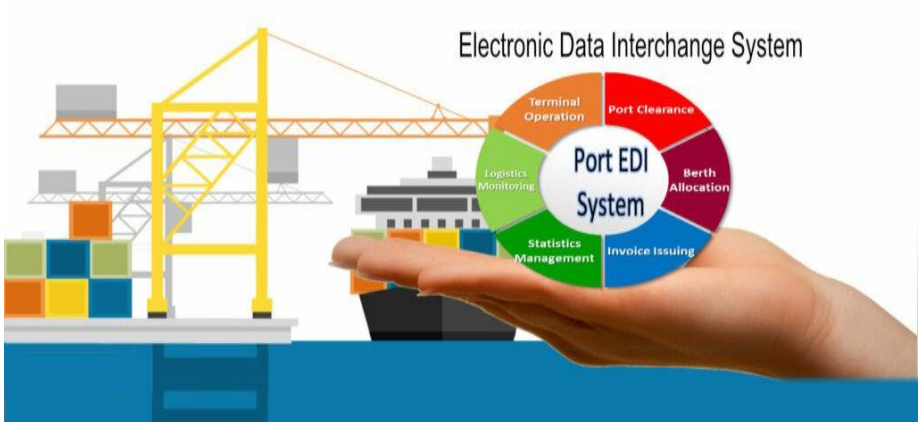

Figure (4): Electronic Data Interchange
Source: Myanma Port Authority,2023

5- Smart Port Concept

Irregular endeavours have been undertaken to build a smart port. Nevertheless, there is currently no universally recognized and standardized definition for the term "smart" within the context of ports
and the marine industry. Tracing the etymology of the word "smart" in related domains helps. assists us in comprehending the reasons for the emergence of this word.

Within the realm of technology, "smartness" pertains to the inherent ability of a system to perform autonomous computing functions, including self-configuration, self-protection, self-healing, and self-optimization (Spangler et al., 2010).

Smart growth began in the 1990s as a response to worsening trends in urban planning, such as the loss of open space, air pollution, destruction of historic locations, traffic congestion, and rising costs of public amenities that was driven by both government and society.

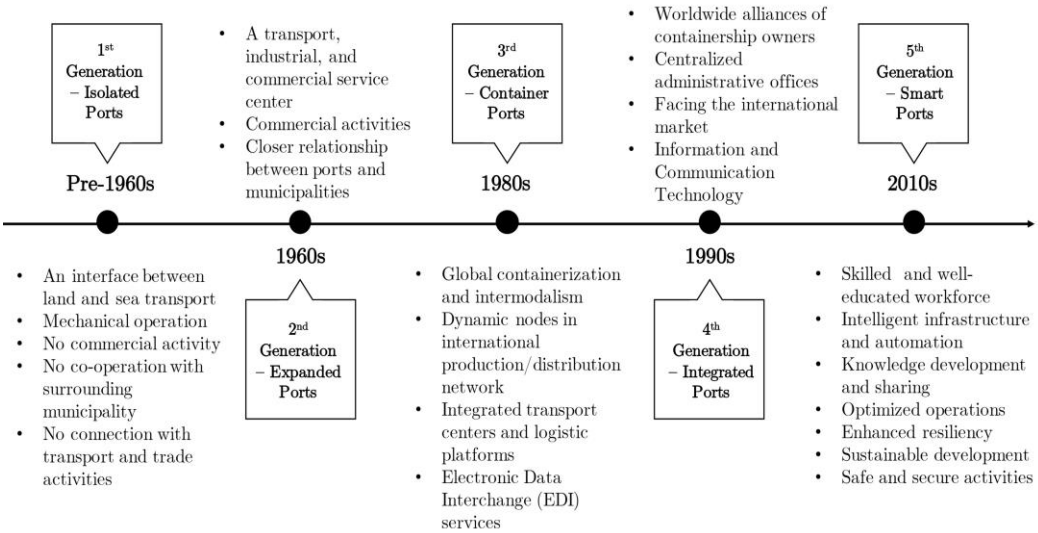

Figure (5) Ports development throughout the history
Source: (UNCTAD 1992, 1999)

A smart port brings together highly educated professionals, skilled labor forces, advanced infrastructures, and automation to promote the acquisition and exchange of knowledge, streamline port operations, improve the port's ability to withstand challenges, promote sustainable development, and ensure the safety and security of activities. The term "smart port" has become widely accepted by both the public and business sectors as an accurate description of the current trend.

Domains	Sub-domains	Description
Operations	Productivity	The extent to which the port operations are carried out efficiently within the limits of time, budget, space, and available facilities
	Automation	Automation is the use of various control systems (set of devices that manages the behavior of other devices or systems) for operating equipment with minimal or reduced human intervention.
	Intelligent infrastructure	Intelligent infrastructure means the use of technologies, both hardware and software, in the port with the aim to increase efficiency and sustainability.
Environment	Environmental management systems	Environmental management systems (EMS) are means to help organizations to improve their environmental performance. This aim is achieved through observing and controlling port operations with regard to their environmental impacts.
	Emissions and pollutions control	Port activities and shipping industry can cause three major types of pollution: emissions to air, noise pollution, and water pollution.
	Waste management	Ports receive a noticeable amount of waste, sources of which are port activities and vessels.
	Water management	Water is a vital resource for both human and other species health, so monitoring and controlling the water quality should be part of port plans and strategies.
Energy	Efficient energy consumption	Several factors influence the energy consumption of a port. These elements could be divided into two categories, direct and indirect energy users. For both groups, saving possibilities should be identified.
	Producing and use of renewables	Renewable energy is replenishable energy that is generated from natural processes. There are significant possibilities of renewable energy implementation in the ports. This assists in partially or totally covering the port energy demand and significantly reduces pollutions.
	Energy management	Ports should identify energy management strategies and activities to make efficient use of the available energy.

Safety and Security	Safety management systems	Safety Management System (SMS) is a comprehensive business management system designed to administer safety principles in the workplace.
	Security management systems	A security management system identifies potential threats to the port and establishes, implements, monitors, reviews, and maintains all appropriate actions to provide assurance for the effective handling of security risks.
	Integrated monitoring and optimization systems	Establishing an integrated monitoring and optimization system based on the most recent software and hardware facilitates achieving enhanced security and safety in the port area.

Table (6) Classification of a smart port activity domains and sub-domains
Source: Anahita Molavi, 2019

6- Smart Port Activity Domains

Table (6) outlines that a smart port is comprised of four primary activity domains: operations, environment, energy, and safety and security. Port performance can be evaluated by analyzing quantifiable components known as "sub-domains" of a smart port. These sub-domains will be further elaborated upon.

6-1 Operations

A smart port employs advanced technologies and implements new and efficient management methods to enhance the efficiency of port operations and reduce associated expenses. The sub-domains encompassed within smart port operations are productivity, automation, and intelligent infrastructure.

6-2 Productivity

According to Statistia (2017), the global capacity of containerships will expand by 1,685,187 TEUs or 8% by 2019. This high growth rate highlights the need of boosting port productivity, since it hasa significant impact on a country's overall productivity. The assessment of port operation productivitycan be conducted by measuring productivity in seven specific areas: berth productivity, infrastructure productivity, land productivity, capacity for accommodating large vessels, utilization of maximum capacity, level of intermodality, and the number of lines calling at the port (MedMaritime SMART PORT, 2016).

6-3 Automation

Automated machinery has the potential to replace human workers in ports, resulting in a decrease in human errors, safety concerns, port congestion, and turnaround time. Additionally, it can improve operational efficiency in port operations (MedMaritime SMART PORT, 2016).

6-4 Intelligent Infrastructure

Integrating advanced hardware and software systems at ports can enhance operational efficiency and sustainability through the real-time collection, analysis, and dissemination of data. Port users

should have access to information regarding the traffic flow of both vessels and hinterland transportation vehicles, closure times of movable bridges, and other infrastructure details.

7- Levels of Transformation into a Smart Port

In order to establish a smart port, there are four distinct degrees of specific actions involved in the process of digital transformation (Figure 7). A port is an intricate system, and modifying one of its components does not automatically make the entire port smart. Instead, a comprehensive digital transformation must occur at these four levels to accomplish this objective.

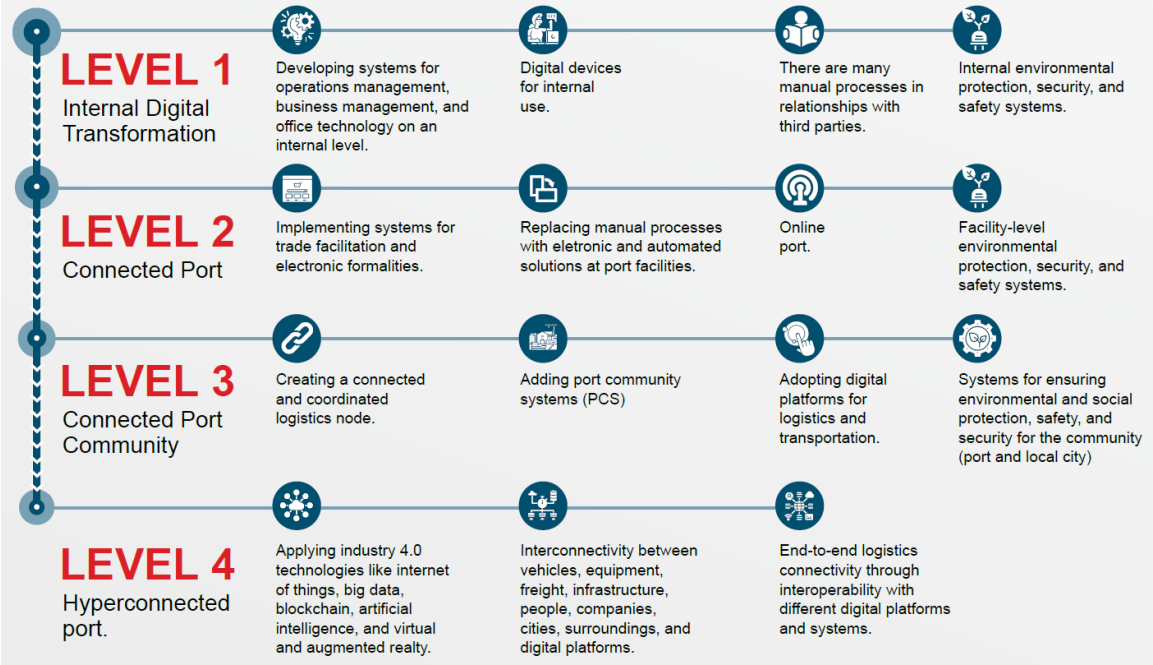

Figure (7) Levels of Transformation into a Smart Port
Source: smart port manual strategy and roadmap

8- Applications of Information Technology in Ports

An intelligent port is characterized by its integration of several 4.0 technologies such as sensors, robotics, Radio-frequency Identification (RFID), IoT, and Big Data. These technologies would significantly improve the port's problem-solving capabilities. In summary, the port operation would be enhanced and the management of the port will be simplified with the implementation of 4.0 technologies. To facilitate quicker and more accurate decision-making in real-time, the Automatic Identification System (AIS) was implemented.

9- Importance of transforming ports to smart ports

The process of digitalization has revolutionized our society, and ports have not been exempted from this transformation. The process of digitizing ports has given rise to what is commonly referred to as ports 4.0, a novel era of smart ports that leverage technology to enhance their operational effectiveness and output.

Ports 4.0 are technologically advanced ports that utilise intelligent systems to enhance their operations and provide more efficient and sustainable services. The port industry revolution is centred around the digitization and integration of various technologies to enhance the efficiency of cargo handling operations.

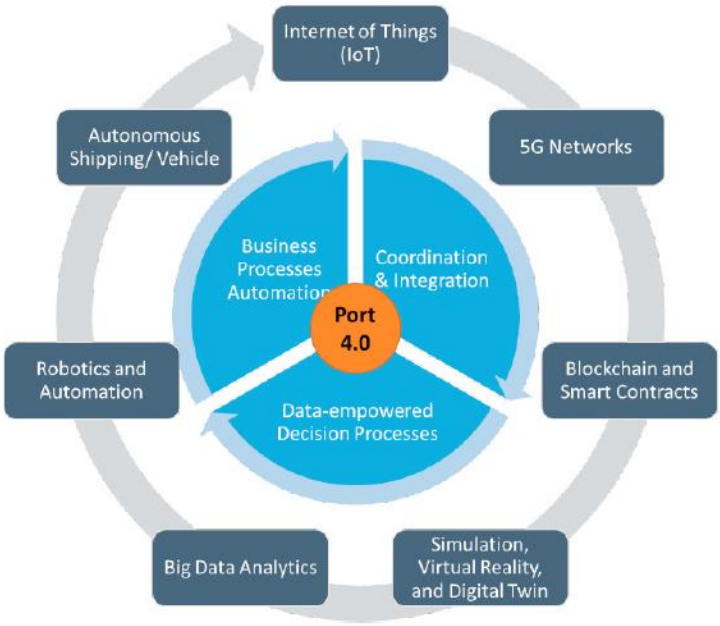

Figure (8) Conceptual Model for Port 4.0
Source: Behzad Behdani.(2024)

10- Port of Rotterdam (Case Study)

In the 14th century, the Rotte was a little fishing village located along the Rotte river. Over the course of six centuries, it has transformed into the largest and most significant port on the continent, and indeed, in the entire globe. Over the course of the previous century, Rotterdam has experienced significant and quick growth, transforming from a modest fishing village into the primary port in Europe.

Implementing automation for each party involved in the port facilitates the gathering of data. This can be utilized to enhance the cost-effectiveness, safety, and sustainability of the port. The introduction of the PMS in Rotterdam has reduced the time it takes for ships to complete their operations by 30 minutes. Given that the cost of a vessel is €10,000 per hour, the total annual savings for the entire port of Rotterdam would amount to approximately €150 million. Decreasing the number of incidents leads to annual savings of €7 million. By optimizing the deployment of port staff, annual savings of €2 million can be achieved. For example, it is evident that despite the growth of Maasvlakte 2, the workforce of the Harbour Master's Division has decreased. The PMS in the port of Rotterdam yields an annual save of around €160 million.

11- Singapore port (Case Study)

Singapore has created and implemented the following advanced technologies and intelligent systems: Firstly, secondly, thirdly, fourthly, fifthly. The Next-Generation Vessel Traffic Management System (NGVTMS) utilizes data analytics and machine learning to detect areas of high traffic and employs advanced algorithms to forecast probable collisions. The VHF Data Exchange System (VDES) enables secure and dependable data transmission between ships and between ships and shore. digitalPORT@SG™ is Singapore's Maritime Single Window, a comprehensive platform that facilitates port call transactions and regulatory clearance. The Singapore marine Data Hub is a comprehensive platform for sharing data that facilitates secure exchanges of information to stimulate the creation of creative solutions for the marine industry. DigitalOCEANS™ is a digital platform that seeks to enhance the compatibility between different systems in the global maritime transport chain. It achieves this by creating common data standards and Application Programming Interfaces (APIs) specifically for the maritime industry.

Singapore's marine research and development is advancing according to the 'Singapore R&D Roadmap 2030 - marine Transformation'. This roadmap is based on five main strategic research focuses: i) A highly productive and advanced port of the future, ii) Strategic management of sea space and maritime traffic, iii) Intelligent fleet operations and self-driving ships, iv) Reliable maritime safety and security, v) Ensuring a sustainable marine environment and energy sources. The Port of Singapore is implementing a strategic smart port initiative known as 'NGP (Next Generation Port) 2030'.

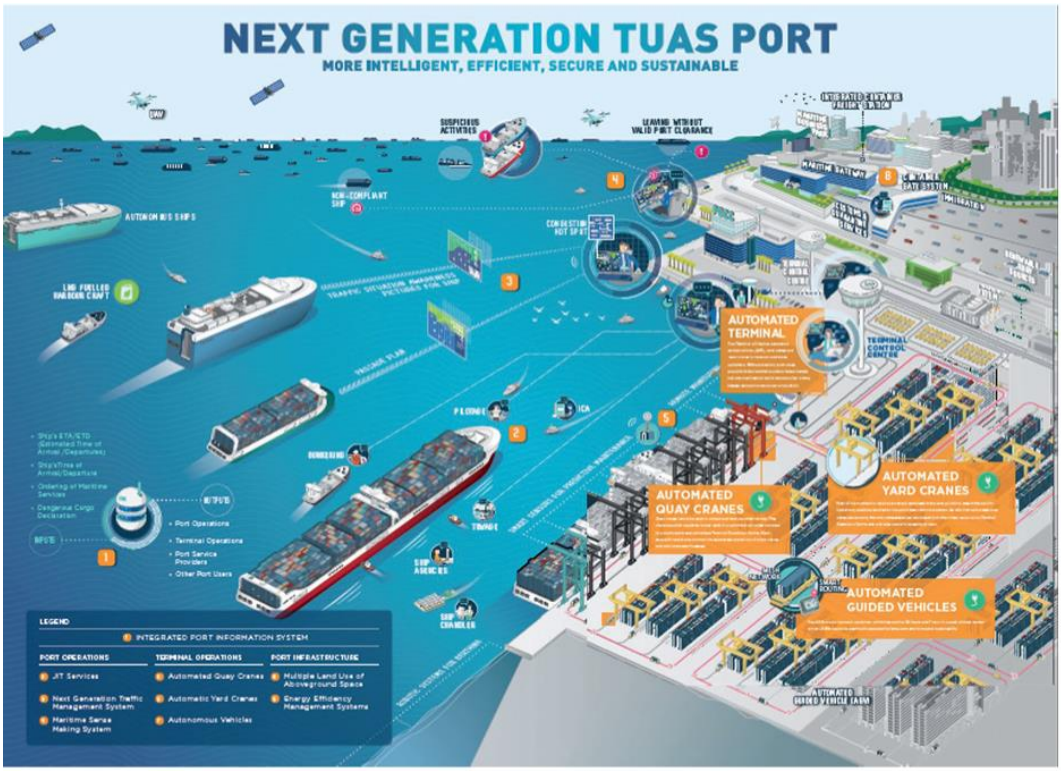

Figure (9): Singapore’s next generation port
Source: Smart Digital Ports (2019)

The NGP 2030 program serves as a framework for the comprehensive strategic planning and growth of the Singapore port. It encompasses the creation, design, and execution of the Tuas terminal, Tuas marine center, and port operations. The subsequent are the principal strategies: This text consists of a series of bullet points. Efficient and proficient administration of harbor waters Enhance the level of security and ensure safety Improve the overall experience of port users Enhance the long-term viability and conservation of natural resources and ecosystems. Singapore's Roadmap 2030 intends to enhance research and development (R&D) efforts and allocate resources more effectively to foster increased collaboration and innovation in the maritime industry.

12- Alexandria Port's efforts in digital transformation

Digital transformation aims to optimize the efficiency, boost the effectiveness, and ensure the long-term viability of logistics services. Additionally, it effectively decreases expenses and facilitates additional advancements to ensure that the port is interconnected with diverse sectors, encompassing the handling of cargo, transportation logistics, and the movement of goods. This integration enables seamless collaboration between ships, cranes, containers, and trucks, resulting in proficient operations within the port.

Alexandria Port aims to become a smart port by utilizing digital transformation solutions, improving infrastructure, and providing training to port personnel as in figure (10). Alexandria Port actively engages in international forums focused on digital transformation.

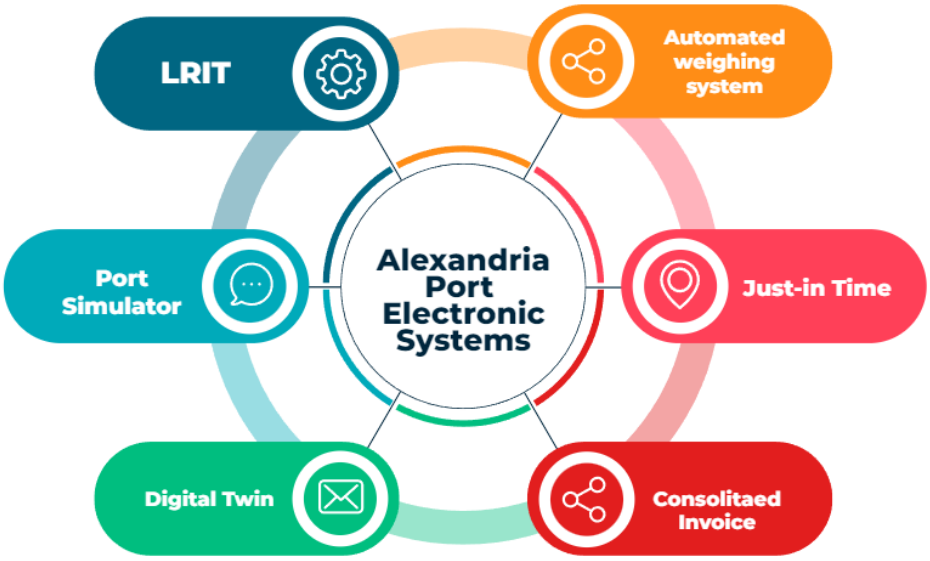

Figure (10): Alexandria Port Economic systems
Source: developed by the author

13- JIT (Just in Time) System for ships

An efficient method designed to complete all necessary tasks within the specified deadlines. By implementing this system in ship operation process, the ship that is arriving at the port will receive precise information regarding the designated time for mooring. Similarly, the ship that is already moored will be notified of the exact time for departure. The objective of this method is to

minimize the duration of the ship's waiting period prior to entering port. This system will minimize detrimental emissions to the environment while also decreasing operational expenses.

Figure (11): Benefits of Just-in time system
Source: Teqplay website (Online)

14- Digital Port Twin

A digital port twin is a computer-generated model that accurately simulates a physical port, encompassing its infrastructure, equipment, and operational activities. This method employs data, sensors, and real-time three-dimensional models to generate a precise digital representation of the port. A digital twin refers to a virtual replica or representation of a physical object, system, or process. It encompasses a comprehensive digital model that captures the characteristics, behaviour, and functionality of the real-world entity it represents.

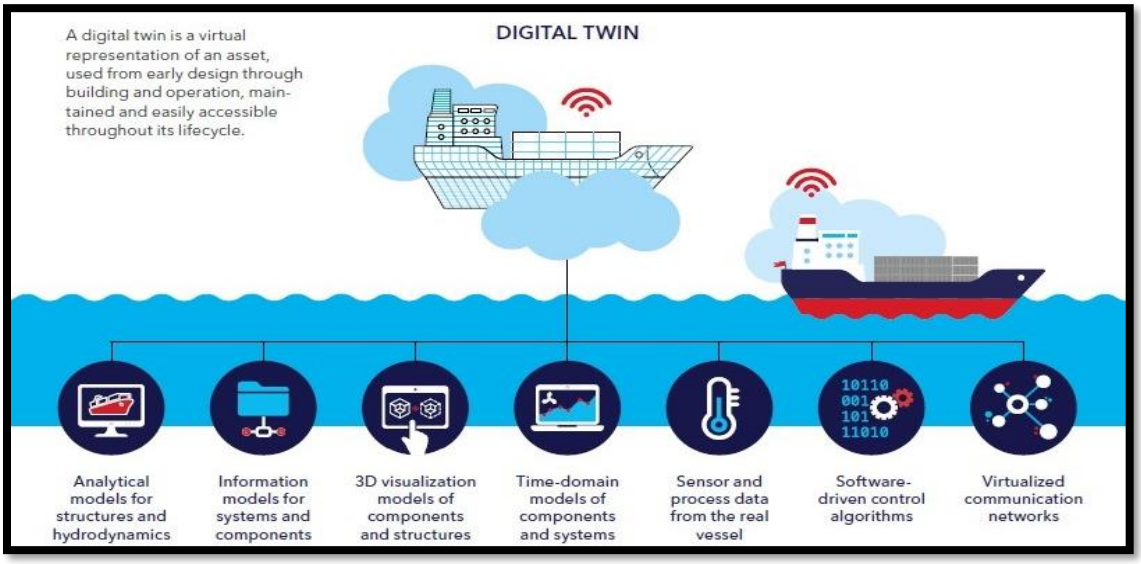

Figure (12): Digital Twin system overview
Source: Arash-Javadi (Online)

15- Smart Port Solution (SPS)

The SPS system's objective is to automatically generate invoices immediately after the completion of procedures, thereby enhancing and augmenting the port's efficiency in relation to its clients. The system is designed to incorporate rules, calculation categories, and variables (such as sunrise and sunset times) in a dynamic manner, enabling their modification without the need for programmatic intervention.

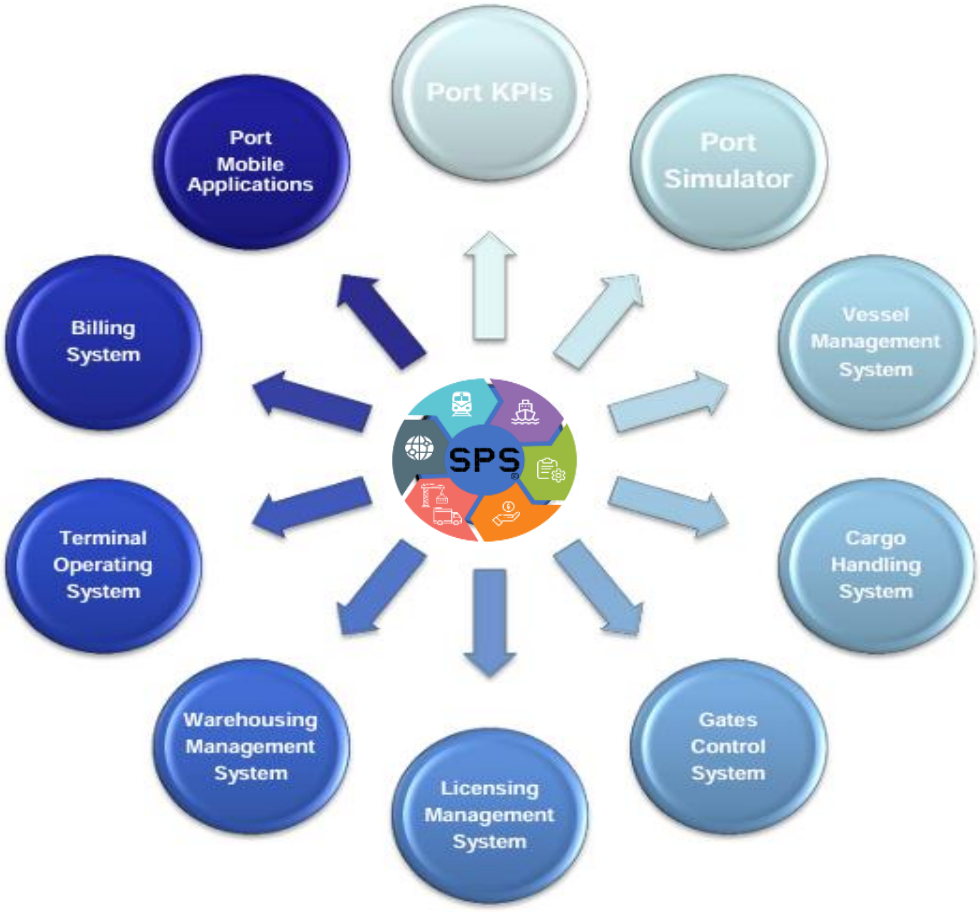

Figure (13): SPS system architecture
Source: Alexandria Port Authority

16- Future perspective for the digitalization of Alexandria Port

In order to facilitate the smart transformation of Alexandria Port Authority, a comprehensive development plan was devised based on an analysis of successful international ports like Rotterdam and Singapore. By identifying the disparities between the achievements of Alexandria Port Authority and these global counterparts, the study formulated a proposal. The digital transformation process, as depicted in Figure (14), encompasses three distinct levels: internal transformation, port community transformation, and intelligent transformation.

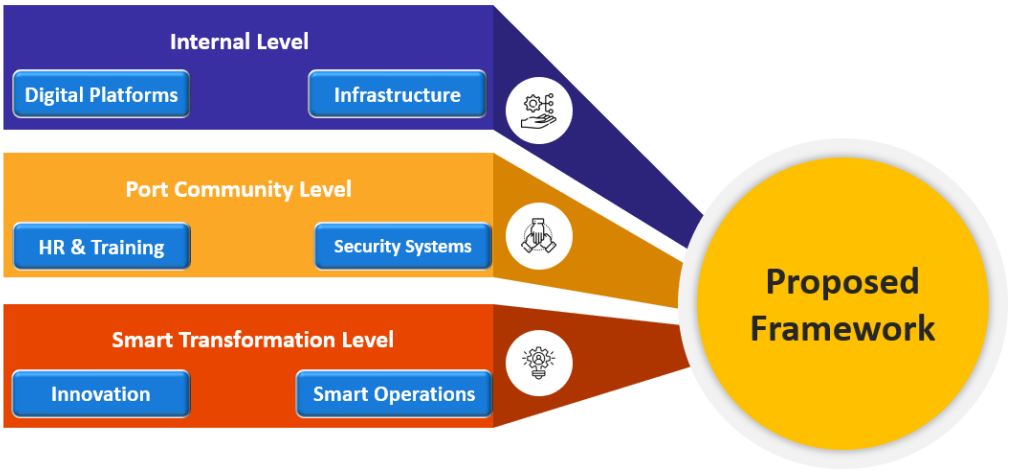

Figure (14): Proposed development of Alexandria Port Authority
Source: developed by the author

17- Conclusion

The objective of this study is to delineate the fundamental duties carried out by smart ports, including the smart ship industry, 5G connectivity, transport automation, and smart containers. Moreover, it provides a representation of the intelligent port concept and emphasizes the essential cutting-edge technologies that form the foundation of these ports.

Several academic and practical research projects have proposed innovative methods to simplify port operations. Notable examples include the Erasmus Smart Port in Rotterdam, the Netherlands, and the Smart Port of Hamburg in Germany.

A smart port refers to the complete automation of all port operations, as well as the real-time communication of all port activities through the automatic transmission of mobile data. This results in a twofold increase in the capacity of ports to carry out and combine port operations.

Hence, the intelligent port optimizes efficiency by streamlining administrative processes and cutting labor costs, while also enhancing monitoring and traffic management capabilities, so alleviating congestion, boosting production, and ensuring worker safety.

A smart port comprises a fusion of sensors, actuators, wireless devices, and database processing centers. This enhances the efficiency and resilience of the services offered by port authorities in a more sustainable manner. The smart port utilizes many key sensors to gather relevant data, including eddy current sensors, ultrasonic sensors, image sensors, inertial sensors, radio frequency identification (RFID), and radar.

Although the ethical and moral perspective of this research is significant, the study serves as a fundamental starting point for developing an effective and unique strategy for the Alexandria Port Authority. Furthermore, to address the clear disparity in the adoption of smart port applications between the international and regional levels.

This research proposed a modern framework for implementation of smart port processes that considers a step toward improving the rank of Alexandria port. The proposed modern framework is based on state-of-the-art technology in the field of smart port applications worldwide. In terms of technology, many modern technologies have invaded IOT, Blochchain and Digital Twin in the last five years. Such great jumps in IT, electronics and communication technologies happened in recent decades, and many advanced technologies have invaded the ports globally.

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